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TITLE: HYPERBARIC THERAPY CAPSULE

TECHNICAL FIELD

This invention relates to a chamber suitable for use by a person for hyperbaric oxygenation for therapy, prophylaxis or general health improvement. It is particularly, though not exclusively, concerned with a hyperbaric capsule suitable for use by one person at home, or for use by a clinic for the treatment individual clients. The capsule may be used with or without oxygen enrichment of air breathed by the user.

This invention also relates to methods for operating such capsules to ensure efficacy and safety.

BACKGROUND TO THE INVENTION

Hyperbaric chambers known in the art are commonly designed for the recompression of divers to mitigate gas embolism, the treatment of patients in a hospital or clinic environment and for diver or athlete training. In much of the art known to the applicant, hyperbaric chambers are massive and complex devices that require expert attendant staff. Such chambers are therefore not suited for home use by individuals without attendants. Moreover, since expert staff will be in attendance while the hyperbaric chambers of the art are in use, no provision is made for the user or patient to open the chamber from within so that he or she can exit without assistance.

In many hyperbaric chambers for use in the clinical environment the patient is required to lie prone in a tube. Indeed, it is important in recompression chambers for the patient to be prone and inclined head-down at an angle of about 30 degrees. This results in the massive construction typical of many such chambers. [See, for example, US patents 4, 727,870 to Krasel, 5,433,334 to Reneau and 6,354,457 to Aaron, and US design patents 346,864 to Reneau and 415,278 to Bowman.] However, it is also important that recompression chambers be capable of being transported to a diver with the bends and rapidly deployed on site. Relatively compact chambers suitable for transport by truck or plane are therefore known in the art. [See, for example, US patents 4,811,729 to Sands et al,

5,378,093 to Santi and 6,321,746 to Schneider. For relatively modest recompression pressures, portable inflatable chambers with flexible walls are also known in the art. [See, for example, the above US patents to Santi and Schneider as well as US patents 5,109,837 and 5,398,678 and to Gamow, 5255,673 to Cardwell and 5,360,001 to Brill.]

The traditional design of a hyperbaric chamber for use in hospitals and clinics is a cylinder with a round door at one end through which the patient can be introduced in the prone position. Such a design appears to have been dictated by the need to minimize the area of the end door so that the force on the door is modest even when the chamber is fully pressurized. Nevertheless, many such chambers have the appearance and claustrophobic feel of totally enveloping 'iron lungs' that prevent the patient from moving significantly – let alone sitting up – and that allow visual contact with the operators through small portholes only. [See, for example, US patent to Krasel above.] The fact that there is generally no way that the user can open the chamber from within exacerbates the natural claustrophobic anxiety associated with enclosure in such a confined space.

Nevertheless, the prior art does disclose designs for hyperbaric chambers that permit the patient to be seated. US patent 5,327,904 to Hannum and US patent 6,352,078 to Harvey disclose short cylindrical chambers of sufficient diameter to accommodate a seated person. In the former case a flat door is fitted into the cylindrical shell and in the latter case the door is set into one end. In both cases, however, the doors open inwards (to enhance strength and facilitate sealing under pressure). Since the open door must allow the user entry and, after entry, must clear the seated user as it is being closed, the size of the chamber still needs to be substantial. Hannum nevertheless notes that an important feature of his chamber is that can be made sufficiently compact to fit through double (hospital) doors. Again, both chambers require the attendance of a skilled operator throughout the treatment of the patient or user, including the opening of the door to permit entry and egress at the start and end of the procedure. Thus neither chamber is suited to home use, for installation in a normal house or for use by a person without assistance.

Finally, it is to be noted that US patent 4,50a - 50d9,513 to Lasley discloses a 'hyperbaric chamber' that appears to be suitable for home use by a person without assistance. However, the device is a bag into which the user climbs like a pair of angler's waders, securing the opening around the upper part of the body (below the shoulders and not including the arms) to form a seal. The bag is then inflated with oxygen-enriched air. Obviously this device is not, in fact, a hyperbaric chamber in the normal sense – that is, one intended for pulmonary oxygenation.

OUTLINE OF THE INVENTION

From one aspect, this invention is a hyperbaric capsule that has (i) an elongate base molding which incorporates the form of a chair and which extends forward from the chair at user foot level and upward above user head level at the back of the chair and (ii) and elongate canopy that extends forward and downward from above user head level. The canopy has an elongate transparent window and is moveable between an open position, where a user can freely move to and from the chair via the side of the capsule, and a closed position where a seated user is fully enclosed by the canopy and base, which together form a hyperbaric chamber. The base molding and the canopy define respective seal-lines that cooperate to form an air-tight seal between the base and the canopy when the canopy is closed. Preferably, the canopy and its window have convex external surfaces that are curved in both the front-to-back and the side-to-side directions, the window preferably extending from at least user head level to the level of the seat of the chair.

The capsule is preferably fitted with latches for securing the canopy to the base at a plurality of points about its periphery, the latches preferably being operable in unison by an actuator located within the capsule and an actuator located outside the capsule. The latches may take the form of hooks mounted on the ends of shafts, which extend transversely through the base, and coacting latch pins mounted on the canopy. The arrangement may be such that outward movement of the canopy sides under pressure is resisted by the hooks and their shafts. However, it is also envisaged that the sides of the canopy may fit within the periphery of the base so that outward movement of the canopy sides is also resisted directly by the periphery of the base. Preferably, where hooks are used

as the latches, they have an over-center action whereby an opening force applied to the canopy acts to bias the hooks further toward their secure or closed positions, thereby inhibiting operation of the actuators to effect the opening of the canopy while it is under pressure.

The chair will normally comprise a back adapted to support the back of the user at a comfortable angle to the vertical and a seat adapted to support the buttocks of the user at a comfortable angle to the horizontal. The base of the capsule preferably includes a floor in front of and below the chair seat adapted to support and accommodate the feet of a seated user. The base, the floor and the seat and back of the chair are preferably all molded integrally from fiber-reinforced plastics material to incorporate a metal base frame to withstand the operating pressure of the capsule. The peripheral base seal-line is preferably made up of (i) a first generally horizontal U-shape periphery that extends from the seat on each side of the chair and around the front foot area of the base, and (ii), a second generally vertical inverted U-shape periphery that extends from below the seat on each side and over the back of the chair. The first and second U-shape peripheries of the base join at an angle below the seat to complete the base seal line. The canopy has downwardly extending triangular side portions that have a corresponding angle so that they will fit into the join of the first and second U-shape peripheries of the base.

With this form of canopy and base, it is preferable for multiple hook-form latches to be arranged around the join between the two U-shape peripheries of the base and for their corresponding latch pins to be arranged in the triangular portions of the canopy, so that lateral movement of the side portions under pressure is resisted in the manner noted above

To doubly ensure that the canopy cannot be flung open forcefully by premature release of the latch means, a pressure-operated lock may be fitted to prevent operation of the actuator as long as pressure within the capsule is greater than that outside. Preferably, this lock is operable within the capsule so that it can be moved manually by a person in the capsule in the event that it does not automatically release after the capsule is depressurized.

The canopy is preferably of a dished elongate oval shape that (when closed) encompasses the base from the floor area to the top of the chair back. It can be formed from a thick sheet of highly transparent thermoplastic material by applying heat and fluid pressure – without the need for a mold – to generate the desired shape. Since the transparent portion of the canopy can extend in the front-to-back direction from over the head to near the feet of a seated user and, in the side-to-side direction, over the width of the user's body, there is little sense of claustrophobia. An edging of fiber-reinforced plastic material can be applied to the periphery of the canopy to form the canopy seal line and to mount the latch pins and other fittings (such as hinges and gas struts).

The canopy is preferably hingedly attached to the base at the front of the foot area so that it can pivot forwards to allow ready ingress and egress of the user from the at least one side of the capsule. The weight of the canopy may be supported in the open or partially open position by the use of gas struts or the like located at the front of the canopy on each side near of the floor. A flexible rubber-like sealing ring can be readily fitted to the periphery of the canopy and/or that of the base to ensure a substantially hermetic seal therebetween along the respective seal-lines of the base and the canopy, when the canopy is closed.

It will be appreciated that a capsule of the type described can be readily made to be small enough to fit through the standard doorways of a normal domestic dwelling and to be handled by one or two installers, particularly if the base is provided with wheels. However, because of its small size and volume, it is desirable that there be adequate provision for heat and CO_2 removal. This may be achieved by ensuring sufficient flow of pressurized air through the capsule while it is in use. The pressurized air may be conditioned to user-controlled temperature and humidity. Additionally, heat-exchanger means may be provided to cool the base or chair of the capsule.

If oxygen supplementation is required, it will generally be most safe and economical for the user to employ an oxygen mask while sitting in the capsule. Alternatively, the input air to the capsule can be enriched with oxygen.

With single-person use in mind, it is desirable that pressure, temperature and air/O_2 flow controls and/or indicators are located conveniently within the capsule, preferably on the base thereof or on a lower portion of the canopy. Various audible and/or visual alarms may also desirable; for example, a power-failure alarm, an excess temperature alarm, and an excess CO_2 alarm. Preferably, these indicator, controls and alarms are duplicated on the exterior of the capsule. The activation of any of the alarms may be arranged to automatically depressurize the capsule and even to operate the actuator to release and 'pop' the canopy. A standby pressure vessel or electric battery may be needed to effect such functions despite a mains power failure.

DESCRIPTION OF EXAMPLES

Having portrayed the nature of the present invention, a particular example will now be described with reference to the accompanying drawings. However, those skilled in the art will appreciate that many variations and modifications can be made to the example, and many other examples can be devised, without departing from the scope of the invention as outlined above. In the accompanying drawings:

Figure 1 is a perspective view of the capsule of the chosen example with the canopy closed and a user seating inside.

Figure 2 is a perspective view of the capsule of Figure 1 with the canopy open and no user visible.

Figure 3 is a longitudinal cross-section of the closed capsule taken on plane III-III of Figure 1, the user not being shown.

Figure 4A is a perspective view of the underside of base and canopy frames with the canopy frame in the closed position, showing the manner in which the multiple latches are operated in unison.

Figure 4B is a side elevation of the base and canopy frames of Figure 4A with the canopy frame in a half open position.

Figure 4C is a side elevation of the base and canopy frames of Figures 4A and 4B with the canopy frame shown in the closed and latched position.

Figure 5A is an enlarged elevational detail of one of the latches of the capsule of Figure 1 in its closed or locked position, and showing portion of the latch operating mechanism.

Figure 5B is a sectional view of the latch and mechanism of Figure 5A taken on section line V – V of Figure 5A.

Figure 6A is an elevational detail of the latch and mechanism of Figure 5A shown in the open or unlatched position.

Figure 6B is a sectional view of the latch and mechanism of Figure 6B taken on section line VI – VI of Figure 6A.

Figure 7 is a sectional detail through the base and the actuator handle showing the manner in which the internal and external handles are connected.

Figure 8 is a sectional side elevation, taken on plane III-III of Figure 1, showing the arrangement of the air supply system, controls, alarms and auxiliary equipment suitable for use with the chosen example.

Figure 9A is a sectional detail of a safety interlock in the locked position and Figure 9B is the same view with the interlock in the unlocked position.

Figure 10A is a side elevation of the canopy and base frames in the open position showing a first alternative latching arrangement, while Figure 10B is a similar view to that of Figure 10A with the canopy and base frames in the closed position.

Figure 11A is a side elevation of the canopy and base frames in the closed position showing detail of a second alternative latching arrangement, while Figure 11B is a similar view to that of Figure 11A with the canopy and base frames in the open position.

Turning to Figures 1, 2 and 3, the basic components of the capsule 10 of the chosen example include a molded base 12, which includes an integrally-molded chair 14, and a curved downward and forwardly sloping canopy 16, which includes a large elongate and convex oval transparent window 18 and depending generally-planar triangular panels 20 on each side. Canopy 16 is curved both from side-to-side and from front-to-back and is pivotally attached at the lower front to the front of base 12 by a hinge assembly 22. A gas strut 24 on each side near hinge assembly 22 is designed to both take the weight of canopy and limit the rate at which it can be swung open or closed. In Figures 1 and 3, canopy 16 is shown closed, while in Figure 2, it is shown open. The outline of a person 26 seated on chair 14 is indicated in Figure 1, but not in Figures 2 and 3.

In this description it will be convenient to refer to the space enclosed by canopy 16 and base 12 as the hyperbaric chamber – since it can be pressurized – and to refer to the entire device as the capsule.

As best seen from Figure 2, base 12 has a generally horizontal bottom 28 with a curved front portion 30 and a generally upright back 32 with a curved top 34 portion. Bottom 28 (including curved front portion 30) defines a generally horizontal U-shape that has an upward-facing peripheral edge 36, while back 32 defines a generally vertical U-shape that has a forward-facing peripheral edge 38. The rear of bottom peripheral edge 36 joins the bottom of back peripheral edge 38 at an angle indicated at 40, which corresponds to the angle indicated at 42 of triangular side portions 20 of canopy 16.

While peripheries 36 and 38 could form a continuous peripheral seal-line against which a sealing strip fitted around the inside of canopy 16 could rest, in this example the continuous seal-line 44 is formed by the faces of shoulders 45a and

45b that up-stand from peripheral edges 36 and 38 (respectively). A flexible resilient seal-strip 47 (Figures 2 and 6A and 6B) is fitted around the entire internal periphery of the canopy so that it engages with base 12 inboard of canopy 16. The arrangement is such that, when canopy 16 with attached seal-strip 47 is lowered onto base 12 to the closed position (as in Figure 1), seal-strip 47 is brought to rest against shoulder 45a of bottom 28 of base 12 and against shoulder 45b of back 32 of base 12. Thus, internal pressure in capsule 10 will press seal-strip 47 downwards into sealing contact with bottom 28 and backwards into sealing contact with back 30. [This is shown and described in more detail with reference to Figures 6A and 6B.]

After being lowered to its closed position, canopy 16 can be secured to base 12 by pivoting side hook-like latches 50a – 50c on each side of base 12 to engage corresponding latch pins 52a – 52c each side of canopy 16. A pair of pivoting top hook-like latches 50d engage a common latch pin 52d (Figure 2) located inside the top rear of canopy 16. Latches 50a - 50d are mechanically linked (in a manner to be described) so as to operate in unison, latch 50c (Figures 1 and 2) being formed on the lower end of an external actuator or handle 54. Handle 54 is secured to a transverse shaft 84c (to be further described) that passes through back 30 of base 12 and is connected for conjoint operation with an internal handle 56. Thus, latches 50a - 50d can be operated in unison by person 26 seated in the capsule using handle 56 or by a person outside the capsule using handle 54.

The peripheral edges 36 and 38 of base 12 thus define a recess around base 12 within which the linear peripheral edges of triangular sides 20 of canopy 16 are located when the canopy is closed.

The window 18 of canopy 16 is joined to triangular side panels 20 by a curved fiber-reinforced plastic [FRP] skirt 60 molded onto and around the periphery of window 18, which is blown to shape in an oven without a mold from thick transparent plastic sheet material. Base 12, including the basic shape of chair 14, bottom 28, curved front 30, back 32 and its peripheral edges 36 and 38, is molded integrally from FRP. Included in this molding is a back support 62 and a seat support 64 (Figures 2 and 3) of chair 14 and a foot-well or floor 66 in front of chair

14. Chair 14 is completed by a back cushion 68 fitted on back support 62 and a seat cushion 70 fitted on seat support 64. The peripheral area of base 12 inboard of canopy 16 (when closed) is shaped so as to provide a peripheral land 44a against which seal strip 44 can rest and form a sealing engagement. Thus, closure of the canopy 16 onto the upper part of base 12 forms a hermetically sealed enclosure, except for the provision of inlet slots 72 for the pressurized air at the top of seat back support 62 and the provision of a pressure-regulating exhaust valve 74 between the wall of foot well 66 and curved front 30 of bottom 28 of base 12. A pair of wheels 76 is provided toward the rear of bottom 28 to assist movement of capsule 10 and a pair of adjustable feet 78 is provided near the front of bottom 28 to stabilize the capsule once it is in position (see Figure 3).

The latching mechanism will now be described in more detail with reference to Figures 4A – 5B, which illustrate the engaging peripheries of base 12 and canopy 16 with most other parts removed. The periphery of base 12 incorporates a metal frame 80 that carries hook-like latches 50a - 50d and half of hinge assembly 22. Similarly, the complementary periphery of canopy 16 incorporates a metal frame 82 that carries latch pins 52 and the other half of hinge assembly 22. Frames 80 and 82 are shown in the position for a closed canopy in the Figures 4A & 4C and in the position for a half-open canopy in Figure 4B.

Hook-like latches 50a – 50c are arranged in opposed pairs, one latch of each pair (eg, 50a) being located opposite the other on each side of the base frame, the latches of each pair being are fixed to respective ends of a common transverse shaft. Thus, latches 50a are mounted on each end of shaft 84a, latches 50b are mounted on each end of shaft 84b and latches 50c are mounted on each end of shaft 84c. Short bell-cranks 86a, 86b and 86c are fixed to the centers of shafts or rods 84a, 84b and 84c (respectively), the free end of crank 86a on shaft 84a being pivotally attached to a horizontal actuator rod 88. The free ends of cranks 86b and 86c on shafts 84b and 84c are pivotally attached to a common generally vertical actuator rod 90 behind the back of the chair (not shown). Rear end of rod 88 is pivotally linked to lower end of rod 90 by a bell-crank 92 that is mounted for rotational movement about a fixed transverse tie-rod 93, which – together with similar tie rods 94 and 95 – serve to tie sides of frame 80 together. Upper

extremity of actuator rod 90 is coupled to latches 50d by a push-rod 96. This arrangement ensures that all latches 50a - 50d will operate in unison when motivated by handle 54 or 56, both of which are attached to shaft 84c. Internal handle 56 is secured to shaft 84c within a seal-tube tube 98 (Figure 4A) that prevents air leakage along that handle from within the hyperbaric chamber.

The operation of hook-like latch 50a shown in Figure 1 is illustrated in the detail views of Figures 5A – 6B. As in Figure 1, latch 50a is shown in Figures 5A and 5B engaged with latch pin 52a so that triangular side portion 20 of canopy 16 is locked to bottom portion 28 of base 12. It will be seen from Figure 5A that the throat 53 of latch 50a slopes upwards toward latch pin 52a; that is, it has a re-entrant form such that, when upward force is applied to pin 52a, latch 50a tends to close further rather than open. As described with reference to Figures 4A – 4C, latch 50a is fixed to one end of transverse shaft 84a that can be rotated by bell-crank 86a and actuator rod 88 to engage or disengage latch 50a with its pin 52a, rod 88 being pivotally attached to bell-crank 86a by pin 87. Canopy frame 82 is encased within a molded FRP wall 20a that has a foam core 20b. Similarly, frame member 80 of the bottom 28 of base 12 is encased in an FRP molding 28a, a bearing sleeve 99 being inserted into molding 28a and frame member 80 to carry shaft 84a.

Molding 28a forms the peripheral shoulder 45a on base portion 28 that, in turn, forms upwardly facing seal-line or surface 44. As shown in Figure 5B, a sealing strip 100 (shown here in section) is glued to the inside of canopy side 20 near its bottom and has a flap 101 that rests on seal-line 44 of base portion 28. Under hyperbaric pressure within the chamber, flap is pressed onto seal-line 44 to hermetically seal the chamber. A cushion 103 is glued to the bottom edge of canopy side 20 to cushion the contact between that portion of canopy 16 and base 12 upon lowering of the canopy, cushion 103 not being intended to function as a seal.

It will be noted that the planar triangle-shaped canopy sides 20 will flex outwards toward latches 50a when the capsule is under pressure, stretching seal 100, until sides 20 contact latches 50a. The force thus applied to latches 50a will be

transferred to transverse shaft 84a, which can readily be designed to carry such forces, being in tension. The same considerations apply to pairs of latches 50b and 50c, which are carried by shafts 84b and 84c, as described with respect to Figures 4A – 4C, above.

Figures 6A and 6B are similar views to Figures 5A and 5B respectively and show side 20 of canopy 16 slightly raised from bottom 28 of base 12. In Figures 6A and 6B latch 50a is shown in the open position, having been moved by a pushing force applied to rod 88 that rotates bell-crank 86a, shaft 84a and hook-like latch 50a in the clockwise direction.

Figure 7 is a sectional view illustrating one way in which the internal and external actuator handles 56 and 54 may be arranged on the common shaft 84c in a manner that maintains the desired hermetic seal of canopy-to-base of the capsule. An open-ended bearing tube 98 is molded into the side of back 32 of base 12 to house shaft 84c, the inner end of tube 98 being fitted with a C-clip 104. The central periphery of tube 98 is slotted at 105 to accommodate handle 56 and allow the handle to be moved through a sufficient angle to permit operation of latches 50a - 50d. With shaft 84c in place (ie, passing through) tube 98, an inner bearing 106 for shaft 84c is pushed into tube 98 from its external end along shaft 84c until it abuts C-clip 104, bearing 106 being fitted with a pair of inner O-rings 108 to sealingly engage shaft 84c and an outer pair of O-rings 110 to engage the bore of tube 98. Next, a hub 112 is pushed along shaft 84c into tube 104 until it abuts bearing 106, hub 112 being cross-drilled and threaded to take a corresponding screw-thread 56a formed on the lower end of handle 56. Hub 112 has an O-ring 114 on each side of handle 56 to engage the bore of tube 104. An outer bearing 116 that is substantially the same as inner bearing 106 (including inner an outer O-rings) is then pushed into tube 104 along shaft 84c and the two bearings and hub are held in place by an outer C-clip 118. Finally, outer handle 54 is fitted to the outer end of shaft 84c by cross-pin 119 and inner handle 56 is screwed into hub 106 and into a depression formed in shaft 84c to ensure that handle 56 can rotate shaft 84c. It will be seen that, while shaft 84c is located outside the pressurized portion of capsule 10 and handle 56 is located inside, air cannot escape past the handle 56 out of tube 104 or along shaft 84c.

The pressurization, control and monitoring of the capsule of this example will now be described. In this example independent control and monitoring of the pressure, oxygen concentration (and/or CO_2 concentration), humidity and temperature of air in the capsule is provided. The need to be able to set the desired pressure in a hyperbaric chamber is, of course, obvious. However, the need to monitor for temperature, CO_2 and humidity is dictated by the fact that these variables can quickly rise to uncomfortable – even dangerous – levels in a capsule of small volume like that of the chosen example. If supplemental oxygenation is not used, oxygen monitoring is desirable to (i) ensure that the oxygen concentration of air in the capsule does not fall significantly below that of the atmosphere and (ii) to generate an alarm in the event of an excessive rise. When supplemental oxygenation is used, it may be via a mask or via oxygen injection into the pressurizing air. In that case, it is desirable to have a separate indicator of mask oxygen concentration, and the readings of CO_2 or oxygen concentration in the capsule air may then be of little significance. Control of pressure, temperature and humidity can be achieved by known air-conditioning techniques and apparatus, except for the need for an air pump or blower of higher than normal pressure.

Figure 8 illustrates the basic arrangement of indicators and controls for the chosen example. An external set of indicators and controls is shown at 120 on the side of upright back 32 of base 12 of capsule 10. Internally, a set of indictors (comprising meters and alarms) is mounted in box 122 located at the bottom front of canopy 16 so as to face a seated user. A set of controls 124 is mounted on the inside of one of canopy panels 20 so as to be convenient for operation by the user. The internal indicators and controls 122 and 124 can duplicate the external indicators and controls 120. Cooled air is supplied to the interior of capsule 10 via a pipe 126 from an air-conditioning and pump unit 128 located at the bottom of the rear of base 12. Ideally, unit 128 can be controlled to vary air flow, relative humidity and temperature. The air inlet into the chamber comprises slots 72 (see also Figure 3) located above the back of chair 14. A already noted, air from the hyperbaric chamber is exhausted in a controlled manner through throttle valve 74 and exhaust outlet 130. Pressure regulation is achieved by varying the relative rate at which air flows into and out of the chamber. This may be done by the use

of a fixed air outflow rate and a variable air supply rate, a fixed inflow rate and a variable outflow rate, or by a combination of these methods. A controller unit 134, which accepts inputs from the sensors of monitoring unit 122 and user controls 124, is shown located under the seat of chair 14. Figure 8 also shows an oxygen bottle 136 located in the back 32 of base 12, though no connections are shown to it. Oxygen from this bottle may be used to inject supplemental oxygen into to the input air in pipe 126 or it may be used to provide oxygen to a mask (not shown).

If desired, provision may be made for automatic depressurization and latch release in the event of power failure or excessive chamber air temperature, humidity or CO_2 concentration. Excessive CO_2 concentration and/or temperature can arise where air flow is too low due to malfunction or power failure and may not be noticed by the user in time to take remedial action. In this example, this safety feature is provided by:

(i) ensuring that power failure or the operation of the CO_2 alarm will deactivate air-conditioning and pump unit 128 and open inlet pipe 126 to atmosphere,

(ii) fully open exhaust valve 74, if it is controllable (air will still exhaust from the chamber if valve is not controllable), and

(iii) operate an automatic latch actuator unit 140 that is located in back 32 of base 12 and connected to shaft 84c.

Thus, as soon as the pressure within capsule 10 is equilibrated with atmospheric, the latches will be opened and struts 24 will pop the canopy open enough to ensure circulation of ambient air through the chamber.

Desirably, the CO_2 sensor, controller 134 and automatic actuator 140 should have sufficient standby battery power to operate in the event of power failure. However, the power requirement of actuator 140 may be too large for the standby battery suited to the sensors and controller, so spring, pneumatic or other energy storage means can be used to power unit 140.

A further safety feature envisaged in a modified form of the chosen example is a pressure operated interlock that will prevent the canopy from being opened

prematurely by the user. This may result in forceful and dangerous opening of the canopy if the user has sufficient strength to force internal handle 56 and release latches 50a - 50d. A suitable safety interlock, located in canopy frame 82, is shown in Figures 9A and 9B, which illustrate a modified form of canopy and base. The interlock comprises a diaphragm 142 mounted in canopy frame 82, the diaphragm carrying a slide-bolt 144 for movement outwards to engage a slot 145 in a catch-plate 146 that is fixed to base frame 80. A spring 148 biases bolt 144 away from catch-plate 146 so that, if the chamber pressure approximates ambient air pressure, the capsule can be opened normally and without the need to touch bolt 144. On the other hand, if the chamber pressure is significantly higher than ambient, and if handle 56 is forced to prematurely open latches 50a - 50d, the interaction of bolt 144 and slot 145 in catch-plate 146 will prevent the canopy from opening more than enough to ensure immediate pressure equalization. To fully open the canopy after operation of the latches in this way, where bolt 144 is still extended because of a fault, the user can manually withdraw bolt 144. There will be little resistance to this since the chamber is under no pressure.

The modified canopy side 20 and base bottom 28 shown in Figures 9A and 9B, illustrates another way in which the side forces of canopy sides 20 can be restrained. This is through the side plates 146 that can be placed at intervals around the periphery of the base, as needed, though more than one interlock bolt will not be normally be needed. It will also be seen that the manner in which the seal-line or surface 44 is formed can be varied as desired. Different forms of seal-strip may also be used, though that illustrated is of the same section as strip 100 shown in Figures 5B and 6B (and it has been referenced accordingly).

Other variations of the latching mechanism may also be employed. Some of these are shown in Figures 10A – 11B. In the variant of Figure 10, each side of canopy frame 82 carries two sliding notched latch plates 150a and 150b that engage respective rows of latch pins 152a and 152b located on each side of base frame 80. The sliding plates 150a are on the bottom edge of canopy 82 and are moved backwards and forwards by an actuator lever 154 and are coupled (by means not shown) to upper sliding plates 150b so that all plates move in unison to engage

and disengage latch pins 152a and 152b. Figure 10A shows the frames in the open position and Figure 10B shows the frames in the closed position.

The second variant, shown in Figures 11 and 11B, has mushroom-headed latch pins 160 depending from the bottom of canopy frame 82 that pass and project through holes 162 in base frame 80. Each latch pin 160 can be engaged by an open ended slot 163 in a locking plate 164 to prevent its withdrawal through hole 162. Locking plate 164 is fixed by bolts 165 to a carrier plate 166 that can be reciprocated with respect to base frame 80 by a rack and pinion mechanism 168 that is operated by an actuator lever 170. Figure 11A shows canopy frame 82 removed a little way from the base frame with latch plate 164 in the open or release position. Figure 11B shows latch pin 160 engaged by slot 163 when the canopy (not shown) is in the closed position and latch plate 164 is in the locked position.